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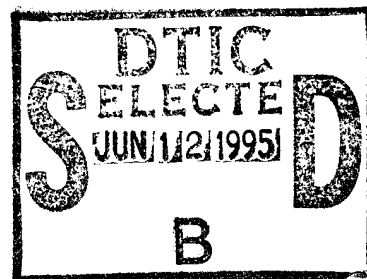# DESIGNING INSTRUCTIONAL SIMULATIONS: EFFECTS OF INSTRUCTIONAL CONTROL AND TYPE OF TRAINING TASK ON DEVELOPING DISPLAY-INTERPRETATION SKILLS

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This report has been reviewed and is approved for publication.

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Instructional simulation is becoming a major vehicle for teaching dynamic technical skills to aircrew members. However, few design principles are available that specify the most effective task formats and strategies for controlling events within instructional simulations. Part- and whole-task training formats and learner- and program-control strategies were investigated separately in two experiments using a microcomputer-based instructional simulation that taught adults how to interpret spatial information on a simple head-up display. These two variables were then completely crossed in a third experiment to examine potential interactions. Program control and part-task training resulted in the best performance, and significant interactions were detected among the two training variables. Implications on the design of instructional simulations are discussed.

14. SUBJECT TERMS

Flight simulation; Instruction; Instructional control; Instructional simulations; Learner control; Part-task training; Program control; Skills; Training; Whole-task training

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PREFACE

This report documents the results of a literature review and three experiments that addressed training design issues relative to Air Force aircrew training using microcomputer-based (desktop) instructional simulation. This report, with some minor revisions, was previously published by Dr. Joseph S. Mattoon (1994) in <u>The International Journal of Aviation Psychology</u>, <u>4</u>(3). The objective of this research was to examine factors that influence the behavior, learning, and performance of adults who engage in training activities via instructional simulations which are commonly used in Air Force training programs and other technical training environments. The work was conducted under Work Unit 1123-25-15, Unit Level Training Research and Applications (ULTRA) group. The work unit monitor was Dr. Bernell J. Edwards, and the principle investigator was Dr. Joseph Sterling Mattoon.

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DESIGNING INSTRUCTIONAL SIMULATIONS: EFFECTS OF INSTRUCTIONAL CONTROL AND TYPE OF TRAINING TASK ON DEVELOPING DISPLAY-INTERPRETATION SKILLS

INTRODUCTION

Instructional simulation is a combination of computer-based training (CBT) and animated computer graphics that is used to teach aircrew and other technical personnel how to perform complex dynamic tasks (Alessi, 1988). The power of these systems lies in the capacity to quickly tailor content material, practice activities, and performance criteria to suit the learning needs of each individual, but research has been inconclusive in specifying the most effective way to organize and control these variables. There are two basic types of instructional control, learner control and program control. Learner-controlled instruction enables individuals to make their own decisions concerning the type and amount of material they receive. In contrast, program-controlled instruction delivers a predetermined body of content and practice or adjusts these activities based on an individual's performance.

Some researchers have recommended learner control for computer-based instruction (Hannafin, 1984; Milheim & Martin, 1991; Tennyson, 1980, 1981), but several empirical studies have often found no effect for instructional control on terminal performance (Gay, 1986; Klein, 1988; Lahey, Hurlock, & McCann, 1973) or concluded that program control is more effective (Avner, Moore, & Smith, 1980; Mattoon & Klein, 1993; Ross & Rakow, 1981). The majority of instructional control studies show that students have difficulty managing their study time, choosing appropriate instructional activities, and setting useful performance goals when they are given control over instruction (Steinberg, 1977, 1989). Some researchers have found that learner control reduces the time learners spend on instruction, but this tends to hinder their achievement unless each individual is provided with advisement when choosing instructional options (Johansen & Tennyson, 1983; Tennyson, 1980, 1981; Tennyson & Buttrey, 1980). Research has not resolved the problems associated with instructional control in conventional CBT, and only a few studies have examined this issue in the context of instructional simulation.

Instructional simulation is a hybrid form of CBT that has become an important medium for helping military and other technical personnel develop complex skills (Alessi, 1988; Gray & Edwards, 1991; Mattoon & Thurman, 1990; Reigeluth &

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Schwartz, 1989). Complex skills are quite different from the declarative knowledge that is acquired from conventional CBT. Declarative knowledge is characterized by a relatively slow and deliberate process of recalling information from long-term memory (Gagné, 1985), whereas complex skills consist of a combination of intellectual, perceptual, and motor abilities and are associated with fast and automatic responses to stimuli (Schneider, 1985). Declarative knowledge can usually be assessed by discrete responses to short-answer or multiple-choice questions, but complex skills are described by continuous measures of accuracy and speed.

A complex task can be described as a number of subtasks that, when executed together or in a sequence, accomplish a single goal (Naylor, 1962). A longstanding theoretical debate continues today on whether to teach learners how to perform a complex task all at once (whole-task training) or break it down into constituent subtasks that are gradually re-integrated into the whole task as learning progresses (part-task training). In part-task training, each subtask is described and practiced as a prelude to attempting the whole task (Gropper, 1983; Naylor, 1962; Stammers, 1982; Wightman & Lintern, 1985). In whole-task training, the criterion task is represented as an integrated whole, and learners practice the entire task. Part-task training has been shown to reduce some of the difficulties learners have when they first attempt to understand and practice a complex task (Briggs & Naylor, 1962; Fabiani, Buckley, Gratton, Coles, Donchin, & Logie, 1989; Frederiksen & White, 1989; Manè, Adams, & Donchin, 1989).

Student pilots and other technical trainees must learn how to quickly and accurately interpret symbolic information from electronic displays. Instructional simulation has proven to be a valuable tool for teaching this type of skill in Air Force training programs (Gray & Edwards, 1991). Instructional simulations can teach aviation students how to interpret a variety of radar and other dynamic readouts from multifunction cockpit displays.

EXPERIMENTAL MATERIALS AND PROCEDURES

The head-up display (HUD) and the radar-electric optical (REO) display are used for similar radar-tracking tasks in military aircraft and provide information that is used by pilots to estimate the location and heading of "targets" (aircraft that have been detected by the pilot's radar). Three experiments examined undergraduates' ability to learn and perform target estimations under different instructional treatments.

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Experiment 1 compared three strategies for controlling level of challenge (task difficulty) during practice. Experiment 2 compared part- and whole-task practice strategies, and experiment 3 examined the joint effects of learner and program control when combined with part- and whole-task training. Subjects estimated targets with the HUD in experiments 1 and 2 and estimated targets with both the HUD and REO in experiment 3.

The instructional simulation used in each experiment was developed with HyperCard software and was delivered by Macintosh computers with 12-inch screens. The en-route and criterion tasks were executed via a computer mouse. Each experiment begin with a CBT lesson that taught subjects how to use a computer mouse to manipulate graphic objects that were part of the simulations. The lesson concluded with a pretest that assessed each subject's initial level of skill with the mouse. The pretest required the subject to "drag" a graphic object, referred to as the "locator," to the center of a small circle of numbers on the computer screen and rotate it to a designated number. This involved the same basic motor skills needed to perform the criterion tasks in the experiments.

The instructional simulation contained verbal descriptions and animated demonstrations of the target-estimation task. Subjects used a mouse to position locator on the screen to estimate each target's location, and rotated the locator to estimate the target's heading relative to the pilot's aircraft (a stationary symbol). During practice, a target symbol appeared after each estimation to show the correct location and heading. A target's angular distance to the left or right of the pilot's aircraft was designated on the HUD by azimuth (a whole number that ranged from zero to 60 degrees) and an arrow that pointed to the right or left. Aspect designated a target's heading and was represented by the position of a pointer along the circumference of a circle on the HUD. Figure 1 shows the HUD, locator, pilot's aircraft, and a target with an azimuth of 45 degrees right and a left-wing aspect (i.e., left wing is pointed toward the pilot's aircraft).

On each trial, the target information was displayed on the HUD, and the locator was centered above the pilot's aircraft. The subject's task was to "click" the mouse on the locator and drag it to the estimated target location, then click on one of the rotate buttons to rotate the locator to the estimated target heading. When the estimation was complete, the subject clicked on a button labeled "done," and the program recorded
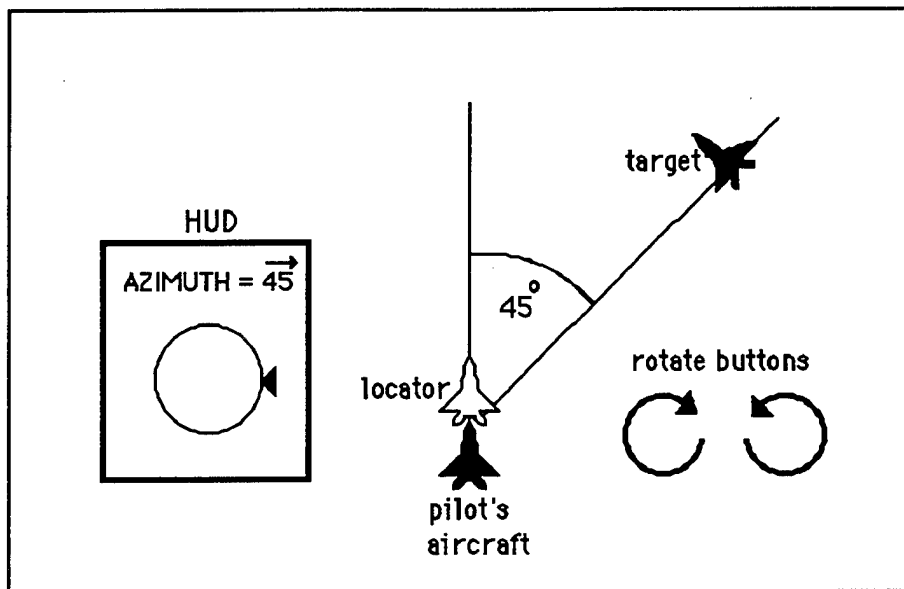
Figure 1.
HUD, locator, pilot's aircraft, and target with
an azimuth of 45° right- and left-wing aspect.

response time (RT) and accuracy and showed the target symbol at the correct position. The subjects were then able to compare the position of the locator (their estimate) with that of the target. No combinations of target location and heading were repeated on practice or posttest items. The posttests consisted of 25 targets to estimate in experiment 1 and 30 targets in experiments 2 and 3. The same target parameters were used in each treatment, and no targets with the same location and heading were used more than once in practice and posttest activities.

Subjects' mean accuracy (average degree of error in target location and heading) and mean RT across posttest items were the primary measures of skill. A multivariate analysis of variance (MANOVA) was used for initial examinations of subjects' training time and their speed and accuracy on the posttests. Follow-up univariate analyses of variance (ANOVAs) were used when significant differences were detected by the MANOVA. A significance level of $p < .05$ was used for all statistical tests. Mean RT on the pretest was used as a covariate to partition subjects' initial skill for using a mouse from the skill they acquired from the instructional simulation.

EXPERIMENT 1

The following experiment was reported previously (Mattoon & Klein, 1993) and is described here after a re-analysis of the data.

Method

Subjects, Materials, and Treatments

Subjects were 61 undergraduates (12 male and 49 female) from a large public university in the southwestern United States who participated in the experiment for partial course credit. The first portion of the program provided subjects with instruction for using the HUD to estimate targets. Seventy-five practice trials followed the HUD instruction. Each trial included one target to estimate. Points for RT were earned according to the ratio--time limit divided by RT--and accuracy points according to the ratio--error limit divided by degrees of error. For each estimate that was within accuracy and speed criteria, a proportional number of points were added to the subject's score, and each estimate that was below criteria caused a proportional number of points to be subtracted.

An increase in speed challenge decreased the time limit (time allowed to estimate a target), while an increase in accuracy challenge decreased the error limit (degrees of error allowed in each estimate). At higher challenge levels, subjects could earn more points for estimates that met criteria, but they also risked losing more points for estimates that were too slow or inaccurate. Challenge level for speed and accuracy were displayed on two scales that ranged from 10 to 100.

The experimental treatments were learner control (LC), learner control with advisement (LCA), and program control (PC). Level of challenge was controlled by the subject in the LC and LCA groups and was controlled by the program in the PC group. The LC version of the program allowed subjects to adjust challenge levels after each practice trial by adjusting a pointer on each challenge scale. The LCA version provided the same learner control over challenge but also displayed advice on control decisions (e.g., "set speed challenge to 35") as a function of the proportion of points earned (or lost) over the most recent five-trial block. The PC version automatically adjusted challenge levels every five trials using the same function that generated advice in the LCA treatment. The program delivered an immediate and a one-week delayed HUD posttest. No challenge levels were used on posttests, but the program repeatedly prompted subjects to estimate targets quickly and accurately.

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Procedures

The experiment was a two-variable mixed design with three levels of instructional control as the between-subjects variable and test occasion as the within-subjects variable. An approximately equal number of males and females were assigned to each treatment in the order they arrived at the computer site. Subjects completed the mouse lesson and pretest, HUD instruction, practice, and immediate posttest, respectively. Each subject returned one week later to complete the delayed posttest.

Results and Discussion

The covariate (pretest RT) was significantly correlated with posttest RT ($r = 0.50$, $p < .01$) and error in estimations of target heading ($r = -0.27$, $p < .05$) on the posttests. Also, error in target location was significantly correlated with error in heading ($r = -0.29$, $p < .05$). The adjusted means for posttest RT are reported in Table 1.

Table 1. RT (s) on Immediate and Delayed Posttests Adjusted for the Covariate

Treatment	Posttest			Across Treatments
	Covariate	Immediate	Delayed	
LC				
M	12.6	13.0	14.6	13.8
SD	4.55	2.47	2.23	2.35
LCA				
M	11.7	14.1	15.8	15.0
SD	4.07	3.21	2.27	2.74
PC				
M	11.9	14.4	14.4	14.4
SD	4.85	3.95	3.96	3.96
Across Treatments				
M	12.2	13.8	14.9	14.4
SD	4.94	3.21	2.82	3.03

Note. Covariate = pretest RT; LC = learner control; LCA = learner control with advisement; PC = program control.

The initial analysis revealed significant differences among treatments, multivariate $\underline{F}(4,55) = 6.02$, $\underline{p} < .001$. A follow-up ANOVA revealed a treatment by test occasion interaction effect on RT, $\underline{F}(2,58) = 4.95$, $\underline{p} < .05$, and an analysis of simple effects indicated that LC subjects performed faster on the immediate posttest ($\underline{M} = 13.0$) than on the delayed posttest ($\underline{M} = 14.6$), $\underline{F}(1,38) = 4.64$, $\underline{p} < .05$. LCA subjects were also faster on the immediate posttest ($\underline{M} = 14.1$) than the delayed posttest ($\underline{M} = 15.8$), although this difference did not reach the assigned level of significance, $\underline{F}(1,38) = 2.81$, $\underline{p} = .10$. In contrast, PC subjects performed at the same speed on both immediate and delayed posttests ($\underline{M} = 14.4$). This interaction is illustrated in Figure 2.
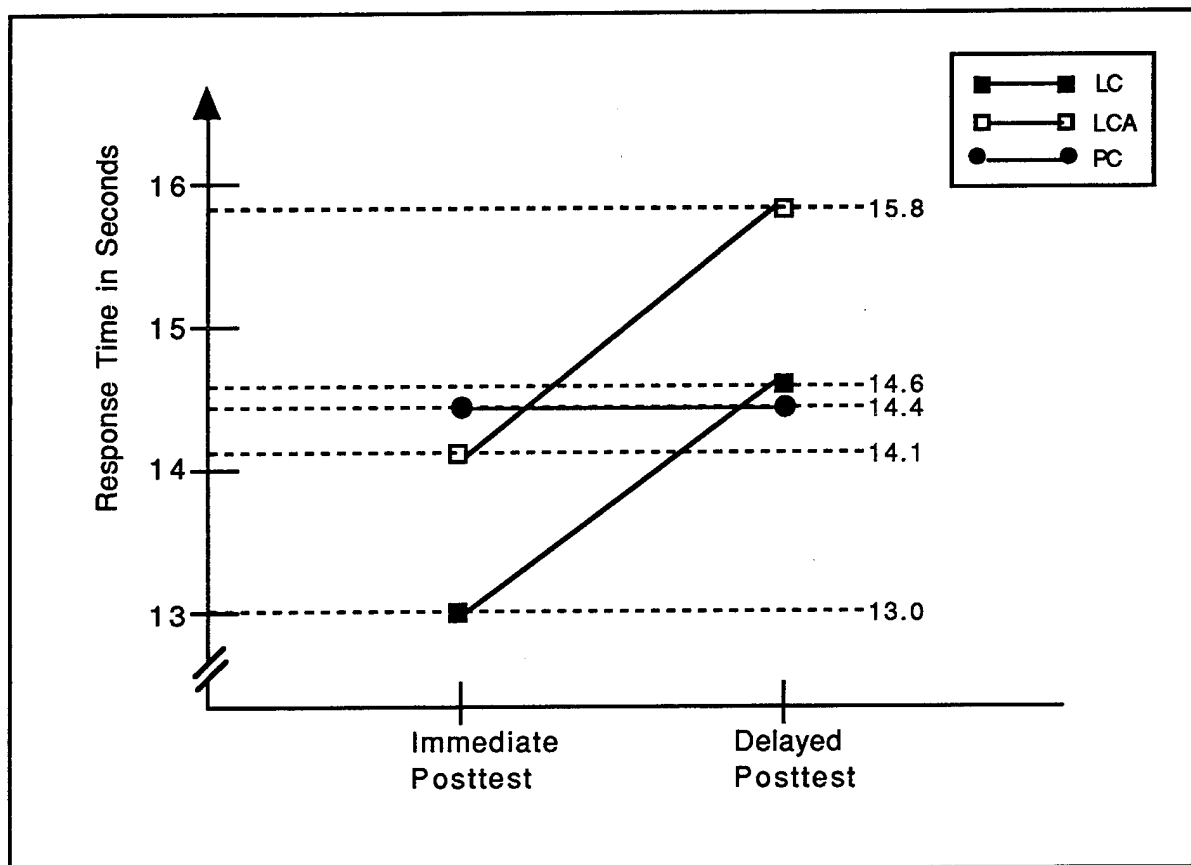

Figure 2
RT on Immediate and Delayed Posttests.

The increase in RT for subjects in the LC and LCA groups may be due to the difficulty they had in recalling some of the concepts and rules of the criterion task. Subjects under learner control had to perform some additional tasks during practice to adjust

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speed and accuracy challenge levels, and this may have interfered with their retention of information. Logan (1985) indicates that additional subtasks which engage the same cognitive resources decrease a learner's ability to acquire a complex skill. Controlling challenge levels can be viewed as such an additional subtask because it required some of the same type of mental calculations as those used to estimate targets. In contrast, the program-control version of the instructional simulation automatically set challenge levels and probably enabled subjects to focus more of their attention on the practice and feedback. This could be the reason that PC subjects did not exhibit an increase in RT across the retention interval.

Subjects under program control may have responded more quickly on the posttests if they would have received practice at lower challenge levels. The average challenge level for PC subjects was higher than the average for LCA subjects on 53% of the practice trials and higher than the average for LC subjects on 73% of the trials. Higher levels of challenge made it harder for subjects to score points and made negative scores more frequent. The consistently high challenge level in the PC group may have induced subjects to be overly cautious and take more time than they needed to estimate targets. Learners' perceptions of their performance during practice probably affect terminal performance and should be carefully considered when instructional treatments are compared.

EXPERIMENT 2

The following experiment was reported previously (Mattoon & Edwards, 1993) and is described here after a re-analysis of the experimental data.

Method

Subjects, Materials, and Treatments

Subjects were 29 female undergraduates from the same university who participated for partial course credit. The program was modified to produce two practice treatments, one progressive part-task and the other whole-task. Both instructional treatments begin with a CBT lesson that described and demonstrated the entire target-estimation task. After the lesson, the part-task version presented six practice exercises (sets of practice trials). Each exercise progressively included practice on each subtask and group of subtasks until the entire task was re-integrated and practiced in the final exercise. The whole-task version of the program required the whole task to be executed in each practice trial.

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Each subject controlled the number of practice trials presented prior the posttest. Part-task subjects practiced 1/3, 1/3, 2/3, 1/3, 2/3, and 3/3 of the target-estimation task, respectively, and were required to complete a minimum of 30 practice trials (5 per exercise). An equivalent minimum for whole-task practice was computed as a function of the proportion of the task presented across the six part-task exercises-- 10/3 x 5-trial part-task minimum = 16.7 or 17 whole-task trials.

Procedures

The experiment was a single-variable, between-subjects design with two levels of training task (part- and whole-task). An approximately equal number of subjects were assigned to each treatment in the order that they arrived at the computer site. Subjects completed the mouse lesson and pretest, HUD instruction, practice, and the posttest, respectively.

Results and Discussion

Significant correlations for the posttest data analysis were pretest RT with target heading error ($r = 0.42$, $p < .05$), posttest RT with heading error ($r = -0.39$, $p < .05$), and target location error with heading error ($r = 0.42$, $p < .05$). The initial analysis of these measures indicated significant differences among treatments, multivariate $F(4,23) = 3.98$, $p < .05$. Univariate analyses showed that subjects in the part-task group estimated targets faster ($M = 16.9$ s) than those in the whole-task group ($M = 20.6$ s), $F(1,26) = 5.11$, $p < .05$.

Table 2 shows the means for number of practice trials completed, RT on practice trials, time on practice, and posttest RT. Part-task subjects spent an average of three more minutes on practice than whole-task subjects, but this difference was not significant. As expected, there were significant differences between part- and whole-task groups for RT on practice trials and number of trials completed, multivariate $F(3,24) = 27.67$, $p < .001$. Part-task subjects completed more practice trials ($M = 51.7$) than whole-task subjects ($M = 17.7$), $F(1,26) = 48.10$, $p < .001$. Also, RT was faster for the part-task group ($M = 17.9$ seconds) than for the whole-task group ($M = 38.2$ s), $F(1,26) = 24.29$, $p < .001$.

The difference in number of trials completed and RT on the practice exercises was not surprising because of the differences in minimum trials and type of practice tasks in the part- and whole-task treatments. However, part-task subjects averaged 72% more practice trials than the minimum number of trials required by the program,

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Table 2. Number of Practice Trials, Practice Trial RT, Time on Practice, and Posttest RT

Treatment	Practice Trials	Practice Trial RT[a]	Time on Practice[b]	Posttest RT[a]
Part-Task				
M	51.7	17.9	14.2	16.9
SD	18.63	5.07	4.53	3.66
Whole-Task				
M	17.7	38.2	11.2	20.6
SD	2.21	16.26	4.66	4.85
Total				
M	36.5	27.0	12.9	18.6
SD	22.0	15.24	4.76	4.54

[a]In seconds. [b]In minutes.

while whole-task subjects averaged only 4% more than the minimum. When the mean number of target estimates is computed according to the proportion of the task that was practiced in each part-task exercise, part-task subjects completed an average of 27.3 target estimates during practice compared to an average of only 17.7 by whole-task subjects. This indicates that part-task subjects chose to complete an average of 54% more practice than whole-task subjects but spent an average of only 27% more time than whole-task subjects (a nonsignificant difference) on practice. Evidently, the part-task treatment enabled subjects to complete more practice in less time than whole-task subjects, and this may account for part-task subjects' advantage in RT on the posttest.

EXPERIMENT 3

The following experiment was reported previously in greater detail (Mattoon, 1994) and is described here after a re-analysis of the experimental data.

Method

Subjects, Materials, and Treatments

Subjects were 48 male ROTC undergraduates from the same university who were paid $15 each for participating in the experiment. The instructional simulation program was further modified to create two levels of instructional control--learner and program control--and two levels of training task--part- and whole-task. Each of four versions of the program consisted of initial instruction on the HUD, four practice exercises with six trials each, additional instruction on the HUD, HUD posttest,

overview of the REO display, and REO posttest, respectively. The REO was similar to the HUD, but it designated target azimuth on a horizontal scale and designated target aspect as a whole number (0 to 180) and a label--"left" for left-wing aspect and "right" for right-wing aspect.

During practice, each target estimate was judged as correct or incorrect based on a single criterion level for speed and for accuracy. The accuracy criterion was met by placing the locator within 7 deg of the correct target location and rotating it to a position within 30 deg of the correct heading. The RT criterion was set at a maximum of 10 s for each half of the target-estimation task (estimation of location and estimation of heading). If a subject estimated 50% or more targets correctly in an exercise, the program encouraged the individual to go on to the next activity by displaying a message on screen--"your performance does not need improvement." If the subject's score was below 50%, a message encouraged the individual to complete more instruction--"additional instruction may increase your accuracy and speed."

In the learner-control treatment, subjects had the choice to complete or bypass a segment of the additional instruction after each practice exercise. The program-control treatment automatically presented additional instruction if less than 50% of the estimates were correct. Each segment of additional instruction consisted of a review of the HUD instruction and strategies for improving accuracy and speed.

In experiment 2, the part- and whole-task treatments were distinguished only by the type of practice they received, but in experiment 3, the part- and whole-task treatments also differed in the way that the initial instruction described and demonstrated the target-estimation task. The initial instruction in the part-task treatment consisted of four separate lessons. Each part-task lesson was followed by an exercise that provided six practice trials. Each exercise required the subject to perform the subtask or combination of subtasks that was taught in the preceding lesson. The fourth part-task exercise provided practice on the whole task.

The whole-task treatment consisted of the same amount of initial instruction and practice trials as the part-task treatment. However, whole-task instruction described and demonstrated the entire target-estimation task in one lesson that was followed by four whole-task practice exercises with six trials each.

An overview of the REO display enabled subjects to alter target parameters on the HUD while observing corresponding changes in target information on the REO.

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The REO posttest was identical to the HUD posttest, except that targets were estimated according to target information shown on the REO. Figure 3 shows the sequence of instructional events for the part- and whole-task treatments.
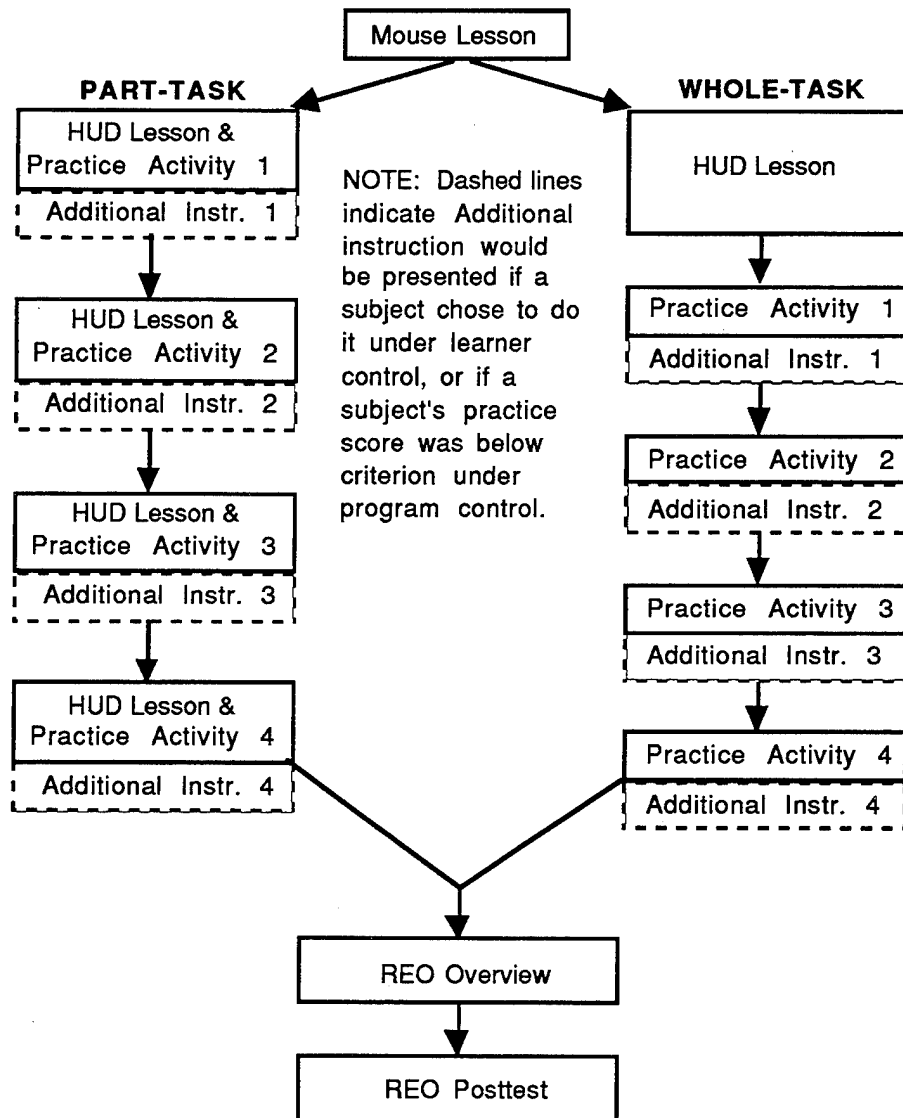

Figure 3
Sequence of Instructional Events for Part- and Whole-Task Treatments.

<u>Procedures</u>

The instructional control and training task variables were completely crossed and manipulated between subjects to produce a 2 x 2 factorial design. An equal number of subjects were assigned to each treatment in the order they arrived at the computer site. They completed the mouse lesson and pretest, HUD instruction, practice, HUD posttest, REO overview, and REO posttest, respectively.

<u>Results and Discussion</u>

Table 3 shows the correlation matrix for dependent variables that were included in the MANOVA. There were significant differences detected among treatment groups, multivariate $\underline{F}(6,38) = 2.94$, $\underline{p} < .05$. Univariate tests showed significant differences among treatment groups for RT on the HUD and REO posttests. The adjusted means for posttest RT are reported in Table 4. Part-task subjects were significantly faster ($\underline{M} = 11.8$) than whole-task subjects ($\underline{M} = 13.4$) on the HUD posttest, $\underline{F}(1,43) = 7.97$, $\underline{p} < .01$. Part-task subjects were also faster ($\underline{M} = 12.4$) than whole-task subjects ($\underline{M} = 13.6$) on the REO posttest, $\underline{F}(1,43) = 5.03$, $\underline{p} < .05$.

Although part-task subjects performed better than whole-task subjects overall, a significant interaction effect on RT on the HUD posttest was also detected, $\underline{F}(1,43) = 12.65$, $\underline{p} < .001$. The interaction indicates that part-task subjects' advantage in speed was mediated by type of instructional control. Part-task subjects were faster under program control ($\underline{M} = 10.8$) than under learner control ($\underline{M} = 12.9$), whereas whole-task subjects were faster under learner control ($\underline{M} = 12.4$) than under program control ($\underline{M} = 14.4$). This interaction is illustrated in Figure 4.

Type of training task had a significant effect on the scores received for each practice exercise, multivariate $\underline{F}(4,40) = 6.04$, $\underline{p} < .001$. Part-task subjects met criteria on more targets in the first exercise ($\underline{M} = 4.3$, $\underline{SD} = 1.37$) and in the second exercise ($\underline{M} = 4.4$, $\underline{SD} = 1.71$) than whole-task subjects ($\underline{M} = 2.7$, $\underline{SD} = 1.58$ and $\underline{M} = 3.1$, $\underline{SD} = 1.10$, respectively), $\underline{F}(1,43) = 15.63$, $\underline{p} < .001$ and $\underline{F}(1,43) = 10.10$, $\underline{p} < .005$, respectively. Part-task subjects also spent less time on the feedback screens ($\underline{M} = 27.5$, $\underline{SD} = 7.62$ s) than whole-task subjects ($\underline{M} = 35.0$, $\underline{SD} = 12.24$ s), $\underline{F}(1,43) = 21.67$, $\underline{p} < .001$. However, differences in practice scores and time on feedback were most likely due to differences in the practice tasks. Portions of the target-estimation task were evidently easier to perform separately than simultaneously. Also, part-task feedback

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Table 3. Correlations Among Dependent Variables

Variable		HUD			REO		
	Pretest RT	Location Error	Heading Error	RT	Location Error	Heading Error	RT
Pretest RT	-						
HUD Location Error	0.42**	-					
HUD Heading Error	0.38**	0.55**	-				
HUD RT	0.39**	-0.05	-0.05	-			
REO Location Error	0.20	0.43**	0.49**	-0.01	-		
REO Heading Error	0.19	0.05	0.33*	-0.01	0.23	-	
REO RT	0.17	-0.19	-0.28	0.61**	-0.11	-0.08	-

Note. HUD = head-up display; REO = radar-electro optical. * $p < .05$ ** $p < .01$.

Table 4. RT on HUD and REO Posttests by Type of Control and Task Adjusted for Covariate

Task	Covariate	HUD Posttest			REO Posttest			Total		
		LC	PC	Total	LC	PC	Total	LC	PC	Total
Part-Task										
M	10.6	12.9	10.8	11.8	12.8	12.0	12.4	12.8	11.4	12.1
SD	1.95	2.02	2.19	2.25	2.01	1.83	1.91	2.02	2.01	2.01
Whole-Task										
M	10.6	12.4	14.4	13.4	13.2	14.0	13.6	12.8	14.2	13.5
SD	1.64	1.60	2.71	2.48	1.53	2.07	1.84	1.57	2.39	1.98
Total										
M	10.6	12.6	12.6	12.6	13.0	13.0	13.0	12.8	12.8	12.8
SD	1.78	1.79	3.05	2.48	1.76	2.17	1.95	1.79	2.20	2.00

Note. Time is reported in seconds. Covariate = pretest response time; LC = learner control; PC = program control.
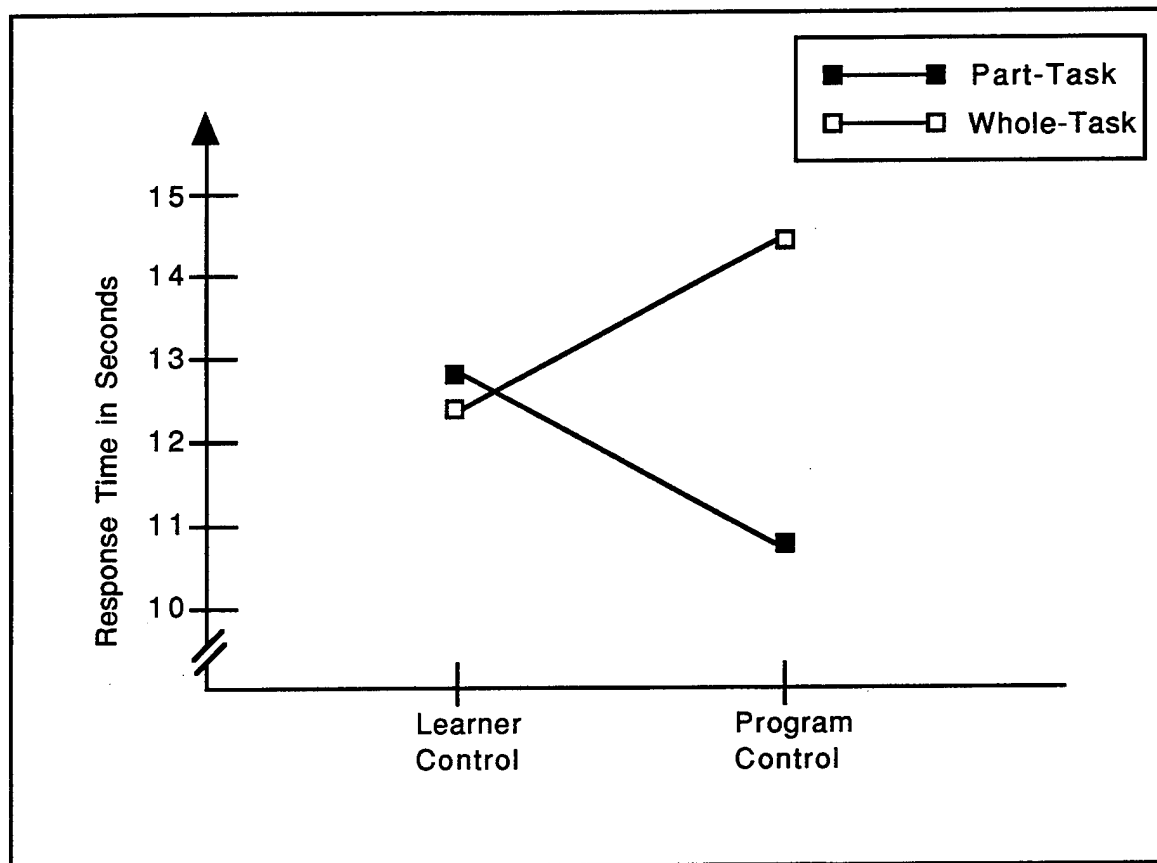
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Figure 4

Interaction of Posttest RT with Type of Control and Task.

(target symbol showing either correct location or correct heading) took less time to examine than whole-task feedback (both location and heading).

The initial analysis of training time on different parts of the program also revealed significant differences among treatment groups, multivariate $\underline{F}(4,41) = 19.23$, $\underline{p} < .001$. Table 5 shows a breakdown of the average number of minutes subjects spent on the HUD lessons, practice, additional instruction, REO overview, and the complete lesson (time summed across the four parts).

Type of training task produced a trade-off in the amount of time subjects spent on the HUD lesson material and the practice. Part-task subjects spent more time ($\underline{M} = 13.1$ min) than whole-task subjects ($\underline{M} = 9.9$) on the lesson material, $\underline{F}(1,44) = 13.88$, $\underline{p} < .001$. However, they spent less time ($\underline{M} = 7.0$ min) than whole-task subjects ($\underline{M} = 9.5$) on the practice, $\underline{F}(1,44) = 25.10$, $\underline{p} < .001$. The difference for time on practice was clearly due to differences in the design of part- and whole-task items.

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Table 5. Training Time (in minutes) by Type of Control and Task

Task	Learner Control	Program Control	Total
HUD Lessons			
Part-Task			
M	13.7	12.6	13.1
SD	3.56	2.92	3.23
Whole-Task			
M	10.2	9.5	9.9
SD	3.30	2.21	2.77
Total			
M	11.9	11.1	11.5
SD	3.79	2.98	3.40
Practice			
Part-Task			
M	6.9	7.1	7.0
SD	1.24	1.43	1.31
Whole-Task			
M	8.9	10.0	9.5
SD	2.05	1.98	2.05
Total			
M	7.9	8.6	8.2
SD	1.96	2.25	2.11
Additional Instruction			
Part-Task			
M	8.3	6.6	7.5
SD	7.97	7.92	7.82
Whole-Task			
M	2.5	10.2	6.3
SD	4.06	7.79	7.25
Total			
M	5.4	8.4	6.9
SD	6.87	7.91	7.48
REO Overview			
Part-Task			
M	2.8	2.5	2.7
SD	0.89	1.30	1.10
Whole-Task			
M	3.0	3.2	3.1
SD	1.14	1.21	1.15
Total			
M	2.9	2.8	2.9
SD	1.01	1.27	1.13
Complete Lesson			
Part-Task			
M	31.7	28.8	30.2
SD	9.72	8.77	9.22
Whole-Task			
M	24.6	32.9	28.7
SD	7.80	9.28	9.40
Total			
M	28.1	30.8	29.5
SD	9.35	9.12	9.24

Most of the practice items in the part-task treatment consisted of only a portion of the target-estimation task, while whole-task items consisted of the entire criterion task.

The causal factors for differences in time on the HUD instruction appear to be associated with the lesson sequence and structure. Whole-task instruction was massed into one lesson that was delivered prior to any practice. In contrast, the distribution of part-task instruction enabled subjects to practice after each quarter of the initial HUD instruction. Whole-task subjects probably became impatient and moved through the instruction more quickly to find out what the task was like, and this may have reduced their ability to understand and retain essential information about the task. Such enroute behavior could account for whole-task subjects' slower RT on the posttests.

A significant control by task interaction effect on additional instruction time was also detected, $F(1,44) = 5.35$, $p < .05$. Whole-task subjects spent far more time on additional instruction under program control ($M = 10.2$ min) than under learner control ($M = 2.5$), whereas part-task subjects spent a little less time under program control ($M = 6.6$) than under learner control ($M = 8.3$). This interaction was produced by differences in the number of segments of additional instruction that were presented in each treatment group.

Subjects under learner control chose to complete 24% of the part-task segments but only 7% of the whole-task segments. In contrast, subjects under program control were routed to only 13% of the part-task segments compared to 23% of the whole-task segments. Part-task subjects under learner control chose to complete a segment of additional instruction on 31% of the occasions that their score was above criterion, while whole-task subjects chose additional instruction on only 6% of these occasions. Also, part-task subjects bypassed additional instruction on only 8% of the occasions that their score was below criterion compared to 15% of these occasions in the whole-task condition. Thus, part-task subjects tended to choose more additional instruction regardless of their practice score and the advisement, while whole-task subjects were more likely to bypass additional instruction even when their scores were below criteria and they were advised to complete it.

The differential use of learner-control options suggests that part- and whole-task subjects did not experience the same cognitive or affective states during training. Unlike the whole-task instruction that immediately described the criterion task in its

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entirety, part-task subjects did not receive a full-task description until the fourth quarter of the HUD instruction. If part-task subjects thought the additional instruction contained a more complete description of the criterion task, they probably chose it for this reason rather than to improve their performance. In contrast, the program-control treatment provided additional instruction on occasions when the individual needed it most. These differences suggest that part-task subjects were better able to effectively use additional instruction when it was presented as a function of their performance. Learners may not be able to effectively use learner-control options in part-task instructional simulations because they lack a robust understanding of the task during initial training.

Whole-task subjects' tendency to bypass additional instruction appears to be related to affective rather than cognitive factors. Having received poor scores during the first two practice activities, whole-task subjects may have become discouraged with the program and were unwilling to spend much additional time on instruction. Students tend to bypass more review and remediation options in a learner-controlled lesson when they do poorly on instructional material (Carrier, 1984; Carrier, Davidson, & Williams, 1985; Gay, 1986). Clark (1984) explains that learners avoid the extra effort associated with choosing additional support options when they expect to fail anyway. Hicken (1991) found that undergraduate subjects bypassed more learner-control options for additional instruction during the most difficult parts of a CBT lesson. The present results indicate that learners under whole-task training may avoid options for instructional support due to the level of difficulty and potential frustration associated with whole-task practice.

Additional instruction appears to have had a negative effect on RT, especially for whole-task subjects. Whole-task subjects under learner control spent the least amount of time on additional instruction but estimated targets 19% faster than whole-task subjects under program control. Whole-task subjects under program control received over three times as many segments as those under learner control. The segments of additional instruction increased the time lapse between practice activities and probably disrupted subjects' concentration on the practice. Munro, Fehling, and Towne (1985) found that program-controlled learners, whose practice was interrupted by feedback messages each time they made an error, performed less well on a complex task than those who were able to control the display of feedback via learner

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control. They concluded that the processing demands associated with complex tasks calls for instruction that does not intrude on learners' attention during practice events. Unlike part-task methods, whole-task training requires learners to acquire all the essential information about a task before attempting to practice it. In such a situation, learners' processing demands and their susceptibility to interference in working memory are probably at the highest level.

GENERAL DISCUSSION

Results of the present studies have several implications for the design of instructional simulations:

1. Progressive part-task training is probably more effective than whole-task training for teaching display-interpretation skills.

2. Instructional events that occur simultaneously with practice activities can produce negative effects on the acquisition and retention of complex skills.

3. Learner and program control differentially affect performance and on-task behavior in part- and whole-task training programs.

4. Program control is probably more effective than learner control if instructional support is delivered in such a way that is minimally disruptive to learners' focus on practice tasks.

5. Learners may be especially susceptible to frustration during the initial stages of whole-task practice, and this may reduce their motivation to expend effort on instructional tasks.

Practice may be the single most important part of instructional simulation, but content material that clearly describes learning tasks is essential for effective practice. Only the instructional content that enables learners to perform a specific practice task should be delivered prior to practice in order to minimize load on working memory. No additional instructional support should be presented unless learners are unable to improve their performance during practice. The need for more instructional support during practice may correspond to plateaus in RT and accuracy. Yet, such information can only be identified and used for control purposes by programs that are sophisticated and powerful enough to collect, record, and analyze multiple responses in real time during simulation activities. Such programs should provide instructional support that is brief and least intrusive to learners' attention on practice tasks.

The present study involved subjects who had no prior knowledge of the task or the environment in which this type of task is normally performed. Additional research should examine the effects of control and training task on pilots who possess more knowledge and skills associated with the interpretation of cockpit displays.

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